REMEDIATING PCB-CONTAINING BUILDING PRODUCTS; STRATEGIES AND REGULATORY CONSIDERATIONS

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ABSTRACT
Following the discovery of building materials containing polychlorinated biphenyls (PCBs), a northeast university undertook a remediation and abatement program for the building. PCB-containing gaskets, caulking, and foamboard were found throughout the building. The PCB concentration in these materials were in excess of allowable limits of 50 parts per million (ppm) for non-liquid PCBs set by the U.S. EPA. In addition, these materials were thought to contribute to the PCB concentrations measured indoors.

A comprehensive sampling strategy identified several PCB-containing products within the building envelope, as determined by sampling the building materials and researching the architectural drawings and plans. Federal, state, and local regulations and interests need to be addressed when dealing with the remediation work and disposal of PCB-containing materials. Specifically, complying with current TSCA requirements can create significant operational and economic challenges.

INDEX TERMS
PCBs, Regulatory Strategies and Implications, Remediation, Building Products

INTRODUCTION
Under the U.S. Environmental Protection Agency (EPA) Toxic Substances Control Act (TSCA), PCBs have been banned in the United States since 1977 due to concerns about their ability to accumulate in the environment and potentially affect public health and the environment (ATSDR, 1996). PCBs were commonly used in a number of industrial processes. These uses included plasticizers, dielectric fluids, hydraulic fluids, and microscope oils (ATSDR, 1996). While production of PCBs in U.S and most of Europe ceased by the late seventies, PCBs continue to pose a risk to the environment due to their persistent nature and their ability to bioaccumulate (UNEP Chemicals, 1999).

PCBs were detected in dust samples taken from the building during an environmental pesticide screening program. Due to sample concentrations in excess of allowable state limits (10 ppm for soil concentrations), University officials closed the building and initiated additional sampling to confirm the existence of PCBs. Additional samples confirmed the presence of PCBs in dust and air, but questions remained as to the possible source(s) of the PCBs. Given the history and location of the building, no obvious external source of the PCBs could be readily identified.

The presence of PCB-containing building materials has not been extensively studied in the United States. While observations have been made about building age and indoor PCB concentrations, much of what is known about indoor PCB contamination or concentrations in

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the U.S. has mainly resulted from acute events involving the accidental release of liquid PCBs (i.e., fires and spills), or the influence of external sources (i.e., plumes, spills, etc) (Wallace 1996, Oatman 1986). Research on the effects of PCB-containing building materials and remediation of such materials from the building environment has been documented in several European studies (Sundahl 1999, Balfanz 1993). These studies have focused on the impact of PCB-containing caulking and other building materials on the indoor environment.

ABATEMENT AND ANALYTICAL METHODS

Abatement work for the building was sequenced into three phases in light of the University's priorities, the layout of the mechanical systems, and the design of the building.

Table 1. Abatement Program Phasing and Tasks

Phase I (Lecture Hall and Low-rise)	1) Removal of window units 2) Ductwork cleaning 3) Decontamination of unit ventilators 4) Decontamination or disposal of building materials
Phase II (Floors 1 and 2)	1) Removal of curtain wall 2) Ductwork cleaning 3) Removal and replacement of unit ventilators 4) Decontamination or disposal of building materials
Phase III (Floors 3 – 8)	1) Removal of curtain wall 2) Ductwork cleaning 3) Removal and replacement of unit ventilators 4) Decontamination or disposal of building materials

The goal of the abatement program was to remove PCB-containing building material from the building in stages that allowed partial re-occupancy of the building. The abatement sequence consisted of the following steps that involved the removal of the PCB-containing building materials followed by the decontamination/abatement of surfaces in contact with the PCB-containing building material:

1) Removal of window components from building
2) Abatement of caulking residues from window openings
3) Removal of PCB containing caulking from window frames
4) Removal and replacement of unit ventilators
5) Removal of PCB containing foamboard
6) Duct and space cleaning and restoration

The phasing of the abatement work required attention and consideration to provide sufficient protection to workers and building occupants in opened portions of the building. Fortunately, the isolation of work areas and the physical layout of the building facilitated the separation of space between ongoing abatement work and the occupied spaces. Protection methods included the installation of containment isolation barriers to prevent the migration of contaminants out of the work space. Access to the work areas was restricted by closing off stairwells and segregating elevator service to the work floors from elevator service to the two occupied floors. Additional measures included weekly monitoring to measure PCB concentrations in the occupied areas. Mechanical systems were operated constantly to maintain constant positive pressurization in the occupied spaces to contain dust and emissions from the work area. Work areas were kept under negative pressure to insure that contaminants would remain within the work area. Portable high efficiency particle air filtration units were used to provide negative pressure within work space areas to minimize dust concentration in the work zones.

Air samples were collected and analyzed using National Institute for Occupational Safety and Health (NIOSH) Method 5503, using a glass filter and florisil sampling train. All samples were analyzed using a gas chromatography/electron capture detector. Results are reported in nanograms of PCB mixture per cubic meter of air (ng/m^3). Wipe samples were collected using pre-cleaned hexane soaked gauze pads. One square foot transects were sampled on high contact surfaces with visible dust accumulation. Samples were were analyzed using EPA Method 8082, as described in EPA Test Methods SW-846. Sample results are reported in nanograms of PCB mixture per square centimeter sampled (ng/cm^2). Bulk materials were sampled following EPA SOP for concrete (1987). All samples were analyzed using EPA Method 8082 and results were reported in milligrams of PCB mixture per kilogram of dust or material (mg/kg or ppm).

ABATEMENT DISCUSSION

Additional environmental samples confirmed the existence of PCBs. The results of this investigation are presented in a separate paper. Possible sources of the PCB contamination were hypothesized. Based on the age of the building, the design of the curtain wall, and information in literature, PCB-containing building products were suspected as a possible source of the PCBs measured in the indoor environment.

Initial steps to confirm this hypothesis included a review of building specifications and architectural plans. 37 potential building materials that were suspected of containing PCBs were listed for sampling based on the review. This review provided crucial information to target materials for sampling. At the time of sampling, a walk-through of the building was conducted to confirm and locate the target list of products and to identify possible sample locations. Based on this list, 52 samples were collected for analysis. Of the sampled materials, the most consistent source of PCBs came from gasket, caulking, and foamboard material used in the building. Concentrations and Aroclor mixtures of PCBs found in building materials are described in the following table.

Table 2. Materials Identified in Confirmatory Sampling

Building Material Category	*Samples*	*Mean Conc. (ppm)*	*Range of Sample Results (ppm)*
Caulking Material	9	6,073	BRL – 33,000
Fill Material	1	BRL	BRL
Gasket Material	18	308	1.1 – 4,300
Foamboard Insulation	6	66	BRL – 310*
Mastic Material	4	2	BRL – 3.9
Tile Material	1	BRL	0.2
Unit Ventilator Components	3	34	3.7 – 63
Vinyl Material	7	3	0.8 – 14
Dielectric Fluids	2	970,000**	970,000**
Other Material	1	BRL	BRL
Conc.: concentration ppm: parts per million, in Aroclor 1254 unless noted BRL: below reporting limit *Result in Aroclor 1221 **Results in Aroclor 1242 Aroclors 1016, 1232, 1242, 1248, and 1260 also tested			

Because concentrations of PCBs in these materials exceeded 50 ppm and their use was not specifically authorized by the EPA, they were considered "unauthorized use" of non-liquid PCB products. The EPA mandated a clean-up program to remove the identified PCB-containing materials and clean the building so that any remaining PCB residues would meet clearance criteria. The classification of these materials as "unauthorized use" was determined by the regulation, despite the fact that the materials were installed prior to the PCB regulations. The abatement plan also included detailed procedures to remove and decontaminate PCB-containing materials from the building without impacting the outside environment. Based on the sampling results of building materials, an action plan for the remediation and abatement of the building was devised and submitted to the EPA for approval. The abatement program required the sampling of 10% of all surfaces and rooms to confirm that all identified PCBs had been removed. In addition, all construction waste in contact with PCB-containing building materials that was to be recycled or disposed as ordinary construction waste had to be tested prior to disposal based on the 10% abatement sampling requirement.

Once cleaned and abated, all surfaces and rooms within the building had to meet a clearance criteria prior to re-occupancy. Clearance criteria for the building was determined by the TSCA program manager. Air samples had to meet a clearance criteria of 1 microgram per cubic meter ($\mu g/m^3$). Wipe samples had to meet the clearance criteria of 10 micrograms/100 square centimeters. Due to the accessibility classification of contaminated materials as classified by the TSCA program manager, remaining porous building components (brick and concrete blocks) had to meet a clearance criteria concentration of 1 ppm.

During the abatement process, adjustments to the abatement plan were required to achieve the clearance criteria. These changes as described below, impacted the schedule and costs of the project. Some of the challenges encountered during the abatement program resulted from the paucity of information regarding the extent of contamination and prevalence of PCB-containing building materials used in the construction industry.

The extent of the PCB caulking residues on and within the brick or masonry surfaces was highly variable as determined by bulk samples. Acceptable depths to meet the 1 ppm criteria ranged from 0.5 inches to 2 inches, or in some cases involved the removal of masonry blocks. One study had indicated that removal of the first 2 millimeters of concrete/brick would be sufficient to reduce the concentration of PCBs to 0.12 ppm (Sundahl 1999). Our experience with this project indicates that the actual depth to achieve a concentration of 1 ppm is highly dependent on the porosity and the finish of the surface in contact with the PCB product. Variability of surface porosity existed in this building, making it difficult to apply a single standard depth for scarifying the masonry surfaces.

The range and extent of PCB concentrations in the caulking and porous brick surfaces presented additional challenges to the abatement project. A grinder connected to a local exhaust mechanism could scarify caulking and surface material to a depth of ½ inch. For part of the building, this depth was sufficient to achieve the 1 ppm clearance criteria. For the remaining parts of the building, this was inadequate due to the porosity of the cinderblock or the application of a caulking tape. Ultimately, in part of the building, existing cinderblocks were removed and replaced to meet the clearance criteria. In another section of the building, channel cuts were made in the brick and then back filled with new concrete in order to meet the clearance criteria. Both of these methods were unforeseen, but were required to meet the EPA-specified clearance criteria.

Mastic found in the front shield of the unit ventilators (182 units throughout the building) had been identified for replacement as part of the abatement program. Measures included the cleaning of all component parts of the unit ventilators. However, additional mastic along the sides of the heating coils was discovered during the cleaning process. This mastic was not visible during the initial sampling phases. Unfortunately, this additional mastic was also found to contain PCBs in concentration in excess of the 50 ppm approved level. Given the age of the existing unit ventilators (approximately 30 years old), it was more cost-effective to replace all of the unit ventilators rather than clean them. The replacement cost also included the disposal of the existing unit ventilators as a TSCA regulated waste stream.

Air samples were collected throughout the course of the project to assess the extent of airborne concentration in the building and to meet clearance criteria for the abatement project. Ongoing monitoring of the abatement work in open areas of the building was also a method of assessing potential exposure to building occupants. Monitoring results as of 12/10/02 of 50 air samples collected, had a mean PCBs air concentration of 0.14 $\mu g/m^3$ (sd 0.11 $\mu g/m^3$), below the NIOSH and EPA guideline of 1 $\mu g/m^3$.

During the summer months, abatement work and temperature effects may have affected some of the monitoring samples. Seasonal effects on indoor air samples for PCBs has been demonstrated in other studies (Pitulle 1995). The Aroclor pattern in the summer air samples resembled the profile found in the foamboard insulation (Aroclor 1221). Whereas the winter sampling appeared resembled a profile similar to the caulking (Aroclor 1254). Surface temperature measurements were made on the spandrel glass to which the foamboard was attached. Temperature taken during sunny days reached 112 degrees Fahrenheit (°F) on spandrel glass containing foamboard. Afternoon temperatures fell to 86 °F in the same location. Indoor air temperatures remained constant during measurements. The elevated surface temperatures due to solar gain may explain the shift in the PCB profile for air samples collected during the summer.

Wipe and bulk clearance samples all had to meet the clearance criteria. Wipe samples were taken from work surfaces, duct work, diffusers, and exhaust grilles. For wipe samples, most samples were non-detectable. Appropriate controls were utilized to insure quality assurance and control. A small number of wipe samples had detectable levels of PCBs, but upon resampling, most samples were non-detectable.

Bulk samples were collected in 10% of all openings in the building during the abatement process. All samples collected met the clearance criteria of 1 ppm. In addition, appropriate and extensive control samples were collected during the abatement process. Samples of unaffected bricks (i.e., bricks not in contact with caulking material) were taken for comparative purposes. Interestingly, one blank sample had low, but detectable levels of PCBs (0.88 ppm).

CONCLUSIONS AND IMPLICATIONS

Under current TSCA legislation, any PCB-containing building material must be removed if the concentration of PCBs is found to be in excess of 50 ppm by weight. Future consideration should be given to measures that manage PCBs in the building, similar to the manage in place approach for asbestos materials. While the effects of low-level long-term exposure to PCBs is not well understood, further research regarding the abatement of PCB-containing materials is important and worthwhile. Building owners and operators need to be aware of the potential economic and operational impacts resulting from compliance with the current TSCA regulations.

Age of a building is a crucial determinant in defining the extent of PCB building material contamination. In addition, curtain wall design may determine the level of contamination or the extent of PCB building material usage. While it is difficult to assess the health impact of the PCB-containing building materials on the indoor environment, the presence of these materials may be sufficient to require a lengthy and expensive remediation program under current TSCA regulations. A critical step in understanding PCB building materials is a review of all architectural plans and building specifications. This review will help focus the search for possible PCB sources. Identifying all possible sources of such materials is time-intensive, but it will help streamline the abatement process in the long-run.

REFERENCES

ATSDR. 1996. *Toxicological profile for polychlorinated biphenyls*, Atlanta: U.S Department of Health and Human Services.

Balfanz E, Fuchs J, and Kieper H. 1993. Polychlorinated biphenyls (PCB) and polychlorinated dibenzofurans and dibenzo(p)dioxins (PCDF/D) in indoor air due to elastic sealants and coated particle boards. In *Dioxin '93: 13th International Symposium on Chlorinated Dioxins and Related Compounds, Vienna, 20-24 September 1993,* Fielder H, *et al.*, eds. Vienna: Austrian Federal Environment Agency, Vol 13, pp 115-118.

Michaud, J, Huntley, S, Sherer, M, *et al.* 1994. PCB and dioxin re-entry criteria for building surfaces and air. *Journal of Exposure Analysis and Environmental Epidemiology,* Vol 4(2), pp. 197-227.

Oatman L, and Roy R. 1986. Surface and indoor air levels of polychlorinated biphenyls in public buildings, *Bulletin of Environmental Contamination and Toxicology,* Vol 37, pp. 461-466.

Pitulle, H, Mohr, S, Benthe, C, *et al.* 1995. Sanitation of a PCB-contaminated building, *Organohalogen Compounds.* Vol 26, pp. 435-439.

Sundahl, M, Sikander, E, Ek-Olausson, B, *et al.* 1999. Determination of PCB within a project to develop cleanup methods for PCB-containing elastic sealant used in outdoor joints between concrete blocks in buildings, *Journal of Envrionmental Monitoring,* Vol 1, pp. 383-387.

UNEP Chemicals. 1999. *Guidelines for the Identification of PCBs and Materials Containing PCBs*. Geneva, Switzerland: United Nations Environment Programme Chemicals.

Wallace J, Basu I, Hites A. 1996. Sampling and analysis artifacts caused by elevated indoor air polychlorinated biphenyl concentrations. *Environmental Science and Technology,* Vol 30, pp 2730-2734.